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FACTORS Affecting Acreage Diverted Under the U.S. Feed-Grain Program

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U.S. Department of Agriculture
Economic Research Service
in Cooperation with
Agricultural Experiment Station
Colorado State University

ABSTRACT

Several factors have significantly influenced the number of acres diverted from production under Government feed-grain programs since 1961. Least-squares regression analyses of historical data suggest that the most important factors affecting the amount of diversion are (1) maximum portion of the feed-grain base farmers are allowed to divert, (2) payment rates for voluntary diversion, and (3) relationship between total support rate and market price. After these three factors have been accounted for, an upward trend in diverted acreage over time is apparent, possibly due to changing attitudes of farmers toward the voluntary program. Statistical models developed also have value as predictive tools, given a continuance of similar types of feed-grain programs.

Key Words: Government feed-grain program response; national; regression analysis; cross-sectional and time series; and secondary data.

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SUMMARY

Since 1961, the U.S. feed-grain programs have been adjusted annually to balance the production and utilization of feed grains. The following interaction of program provisions and economic circumstances has influenced the number of acres taken out of production from year to year during 1961-69:

1. The maximum portion of feed-grain base that farmers were allowed to divert was an important determinant of actual diversion. For example, actual diversion increased by an average of 3.9 percent of the base when maximum diversion allowed was increased by 10 percent of the base.

2. Payment rates for diversion affected level of diversion. As payment for diversion of 20 to 40 percent of the base increased by 1 cent per bushel (corn-equivalent), diversion increased by 0.75 percent of the base. Likewise, an increase in payment of 1 cent per bushel for diversion of 40 to 50 percent of the base was associated with an increased diversion of 0.036 percent of the base.

3. Higher total support rates relative to expected market prices were associated with higher diversion rates. For example, on large cash-grain farms, diversion increased by 0.73 percent of the base when the weighted average price difference between expected market price and total support rate increased by 1 percent of the 1964 total support rate.

The above relationships were identified from a national, or pooled, least-squares regression model. In addition, separate regression models were estimated for individual States and regions. The variables of these individual State models are similar to those of the pooled model and bear the same interpretations. However, some coefficient differences between the pooled model and the State models are significant, and the individual models are expected to yield more accurate predictions. Expected errors associated with estimates of diversion from these individual models are quite low, ranging from 0.43 percent of the base for the Northeast region to 4.40 percent of the base for Louisiana. The models explained over 85 percent of the variation in diversion in each of the major feed-grain producing States except Oklahoma.

The estimate of total 1969 feed-grain diversion in the United States--predicted through use of the individual State models--was 39.3 million acres. This compares favorably to the actual 1969 diversion--39,065,818 acres.

Because of similarities of coefficients for each variable among States and regions in all models, significance of the coefficients in the pooled model, and correspondence of these coefficients with the more general body of economic theory, a high level of confidence can be attached to the relationships. Predictions associated with the final set of models are expected to be quite accurate. Therefore, it appears that the objectives of the study reported here--identifying relationships and constructing predictive models--have been satisfactorily met.

Nevertheless, care should be taken in using the models for predictive purposes. Over the range of 1961-69 experience, differences between the model estimates and true relationships appear quite small. However, standard confidence intervals for regression predictions widen as estimates are based on values of independent variables further away from the historical means. As a result, errors may become quite large when predictions are based on values of independent variables that are outside the 1961-69 range of experience.

FACTORS AFFECTING ACREAGE DIVERTED UNDER THE U.S. FEED-GRAIN PROGRAM

by

Thomas A. Miller and Stanley H. Hargrove[1]

INTRODUCTION

The Problem

U.S. agriculture has been lauded for its productivity. Yet farm income has not kept pace with this increased productivity because expanding production, in the face of relatively static demand, has resulted in lower prices for agricultural commodities. Indications are that expanding productive capacity and static demand are likely to characterize U.S. agriculture for some time.

Initial Government attempts to bolster farm income were made through the commodity purchase activities of the Federal Farm Board. Since the basic agricultural problem was one of chronic overproduction, the Board's activity was by itself unsuccessful. Later, the Agricultural Adjustment Act of 1933 and subsequent legislation included provisions for production adjustment. However, major emphasis was placed on supporting prices through Commodity Credit Corporation (CCC) loans and purchases. As a result, by 1961, the CCC had stocks of 74.7 million tons of feed grains, as well as large stocks of other commodities (11, p. 99).[2] The apparent inefficiency of this program dictated that more steps be taken to control the production, as well as increase the prices of agricultural commodities. To this end, voluntary programs to control the supplies of major commodities were created.

The Government feed-grain program initiated in 1961, as well as subsequent programs, is the focus of the study reported on here.[3] The programs were designed to provide a desirable level of farm income and to balance production and utilization of feed grains at an acceptable cost to the Government. Under the program, CCC loans on feed grains are available only to producers who limit feed-grain production. Since the program is voluntary, it relies on the stimulus of economic incentives to elicit reductions in supply. As production, stocks, and utilization of feed grains change with varying market and production conditions, the amount of reduction desired also fluctuates. Specific incentives employed in the program are adjusted to meet these changing production requirements.

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[2] Underscored numbers in parenthesis refer to items in Literature Cited, p. 25.

[3] Hereafter, the word "program" in the singular form is used throughout this report in reference to one basic program in which annual changes are made as necessary.

The Secretary of Agriculture has the responsibility of making annual adjustments in the program to meet current requirements. To that end, the U.S. Department of Agriculture (USDA) annually appraises supply and demand conditions to determine appropriate production. Through reliance on estimates of response to various program provisions, specific provisions of the annual programs are formulated.

Changes in the basic structure of the program may be made by the Congress. These changes can affect the kind of program offered or redefine the options of the Secretary, or both. Norms mentioned for annual adjustments also apply when more major changes in the program are being considered. Another prime consideration is the acceptability of the program to farmers and the general public.

Objectives of the Study

To make adjustments, either major or minor, policymakers rely partly on information regarding producer response to changes in the program. Annual adjustments are made on the basis of estimates of response to similar adjustments in the past. Changes in the kind of program offered are evaluated on the basis of information concerning the economic decisionmaking processes of groups of farmers.

The primary purpose of the study reported on here was to analyze the response to changing specific provisions of the feed-grain program. Estimates were made from measurement of response to annual changes from 1961 to 1969. In this framework, a mathematical relationship between various program provisions and diversion of feed-grain acreage to noncrop use was identified. Multivariate regression analysis was used to estimate parameters of the relationship.

Previous published research in this area has concentrated on identification of farm characteristics associated with rate of participation, rather than rate of diversion. Sharples and Tompkin (1) and Vermeer (15 and 16) have used farm survey techniques. In 1967, Slaughter (2) made a statistical analysis of Illinois county data. At that time, however, time-series data on program experience was inadequate for an analysis of the effect of different program provisions on participation. The present study, then, differs from previous work in its attempts to determine the effect of different program provisions on the rate of diversion, rather than to describe characteristics of participants. Also, additional years of data are currently available on which to perform a more comprehensive statistical analysis than was possible in earlier studies.

PRELIMINARY ANALYSIS

Specific provisions of the 1961-69 feed-grain program that are relevant to this report are summarized in appendix A. The first step in identifying factors affecting the amount of diversion was examination of feed-grain program provisions in the light of economic theory. After the likely relationships were identified, a preliminary statistical analysis followed. Based on these results, some variables were redefined and a more detailed statistical analysis performed for the major feed-grain States. An example was then presented in which results of the more complete analyses were used to project the amount of feed-grain acreage diverted nationally.

Theoretical Relationships

Economic theory provides a basis to determine how changing the program provisions affects the response of producers. If the response of hypothetical profit-maximizing farmers can be determined, such response becomes a basis for examining that of actual groups of farmers. The model discussed in this section was designed for this purpose.

There are two sources of increased diversion under the program, each stemming from the program's voluntary nature: (1) Amount of diversion on a farm increases, or (2) number of farms participating increases, or both things occur. The following situations (A and B) illustrate theoretical effects of specified provisions on each of these kinds of change. Both A and B assume a "typical" farm where (1) feed grains are grown primarily for sale; (2) normal (base) production is 10,000 units on 100 acres and is equal to the farmer's actual expected production; (3) average variable cost per planted acre is constant; (4) the farm operates in a competitive environment; and (5) the farmer is a profit-maximizer (profit, in this case, being the return to fixed factors). Both situations also assume that the acreage planted to feed grains equals the feed-grain base when the farm does not participate in the program.[4]

Situation A

Assume the following conditions:

1. Market price is $1 per unit of feed grain.
2. Total support rate is $1.20 per unit.
3. Payment rate for required diversion is total support rate on 50 percent of normal production for the first 20-percent required diversion.
4. Payment rate for diversion of between 20 and 40 percent of the base is total support rate on 60 percent of normal production on the acres diverted.

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[4] Overlooked here is the situation a farmer faces when he wants to plant a feed-grain acreage exceeding his feed-grain base. Then, in deciding whether to participate, the farmer must also consider the loss in income from not growing feed grains beyond the feed-grain base.

5. Payment rate for diversion from 40 to 50 percent of the base is total support rate on 50 percent of normal production on acres diverted in excess of 40 percent of the base.

6. Maximum diversion allowed is 50 percent of the base.

Figure 1 shows total revenue possible for the hypothetical farm under this program. OTU shows total revenue at market price for a nonparticipant. The slope of OTU is normal yield per acre (100 units) times the market price of $1. If the farmer participates, planting must be reduced to 80 acres, but two benefits are realized:

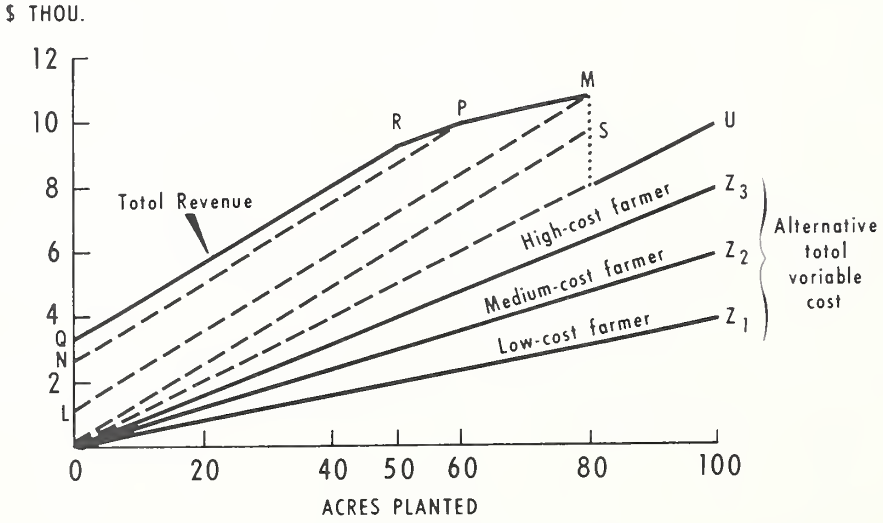
1. Total revenue increases so that OS becomes the appropriate curve--the slope of OS is normal yield per acre times total support rate of $1.20.

2. A payment ($1.20 per unit x 100 units x 20 acres x .50 = $1,200) is awarded for participation.

The total revenue line is thus shifted upward to LM, and total benefits of participation are TM at the 80-acre planting level.

If the farmer diverts 40 percent (40 acres) of his base, he realizes an additional payment ($1.20 per unit x 100 units x 20 acres x .60 = $1,440--payment for diversion from 20 to 40 percent of base), which makes relevant total revenue NP. The segment PM shows total revenue with diversion between 20 and 40 acres.

RELATIONSHIP BETWEEN TOTAL REVENUE AND ACRES PLANTED, HYPOTHETICAL FEED-GRAIN FARM--SITUATION A



DASHED LINES INDICATE REVENUE COMPONENTS AND THE DOTTED LINE IS A DISCONTINUOUS FUNCTION.

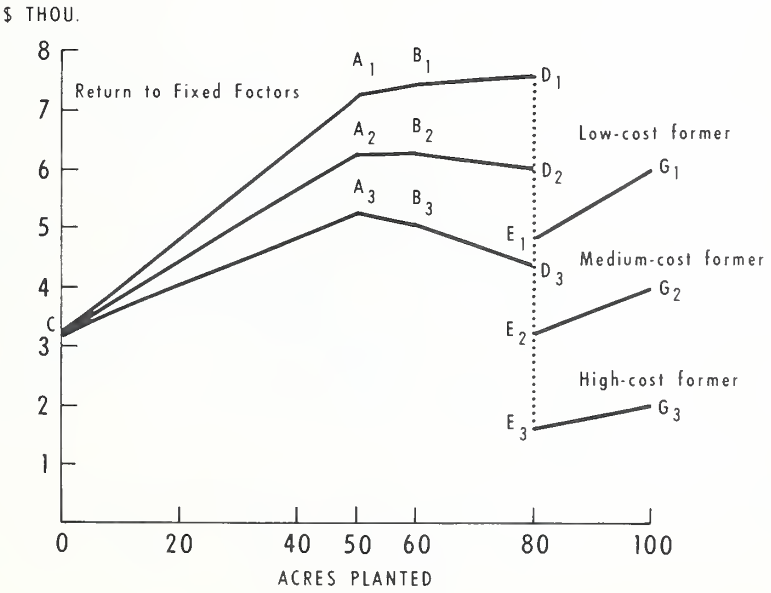
Figure 1

Segment QR is similarly total revenue when the farmer diverts the maximum of 50 percent of the base, and RP shows total revenue for diversion between 40 and 50 percent of the base.

The total revenue curve at all possible levels of participation is given by QRPMTU in figure 1. Examination of this function shows that total revenue is maximized by planting 80 acres--by participating at the minimum diversion level.

To determine the return to fixed factors (profit) at these various planting levels, three different total-variable-cost lines (OZ_1, OZ_2, and OZ_3) were drawn on figure 1. These curves represent costs for a low-cost farmer, OZ_1; a medium-cost farmer, OZ_2; and a high-cost farmer, OZ_3. Profit is the vertical distance between the cost and the revenue lines. On figure 2, lines $CA_1B_1D_1E_1G_1$, $CA_2B_2D_2E_2G_2$, and $CA_3B_3D_3E_3G_3$ show profit possible for farms with low-, medium-, and high-cost schedules, respectively. These curves are discontinuous at 80 acres because of the abrupt increase in price and the beginning of diversion payments as planted acreage is reduced to this level. Maximization of profits is accomplished by planting at the high point on these profit curves: the low-cost farmer should plant 80 acres; the medium-cost farmer should plant 50 to 60 acres; and the high-cost farmer should plant 50 acres. In no case is G (nonparticipation) higher than D (minimum participation)--every farm in situation A would make higher returns by participating.

RELATIONSHIP BETWEEN RETURN TO FIXED FACTORS AND ACRES PLANTED, HYPOTHETICAL FEED-GRAIN FARM--SITUATION A



DOTTED LINES ARE DISCONTINUOUS FUNCTIONS.

Figure 2

Situation B

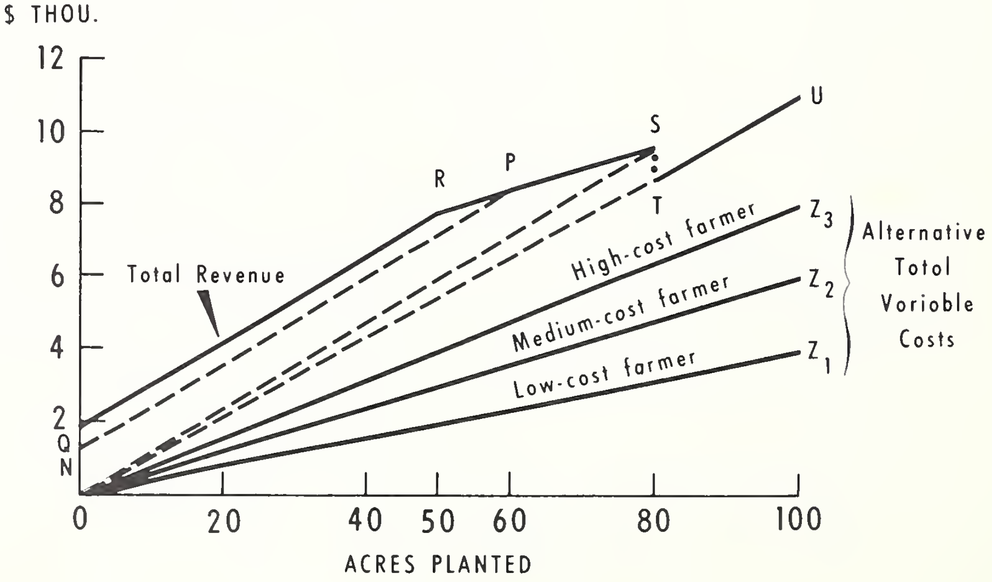
Assume the following changes from situation A:

1. Expected market price increases to $1.10.
2. There is no payment for required diversion.
3. Payment for diversion of from 20 to 40 percent of the base is total support rate on 50 percent of normal production.

In figure 3, segments QRPS and TU correspond to QRPM and TU in figure 1. Since there is no payment for required diversion, segments LM and SM are eliminated from figure 3. Examination of the total revenue curve QRPSTU indicates that total revenue is maximized by planting 100 acres (nonparticipation).

To determine profit in this situation, total variable cost lines OZ_1, OZ_2, and OZ_3 are added to figure 3, as in figure 1. Then $CA_1B_1D_1E_1G_1$, $CA_2B_2D_2E_2G_2$, and $CA_3B_3D_3E_3G_3$ in figure 4 are the respective profit schedules. These indicate the following practices will maximize returns: the low-cost farmer and the medium-cost farmer should produce at G_1 and G_2 (not participate in the program), respectively; and the high-cost farmer should divert the maximum and produce at A_3.

RELATIONSHIP BETWEEN TOTAL REVENUE AND ACRES PLANTED, HYPOTHETICAL FEED-GRAIN FARM--SITUATION B



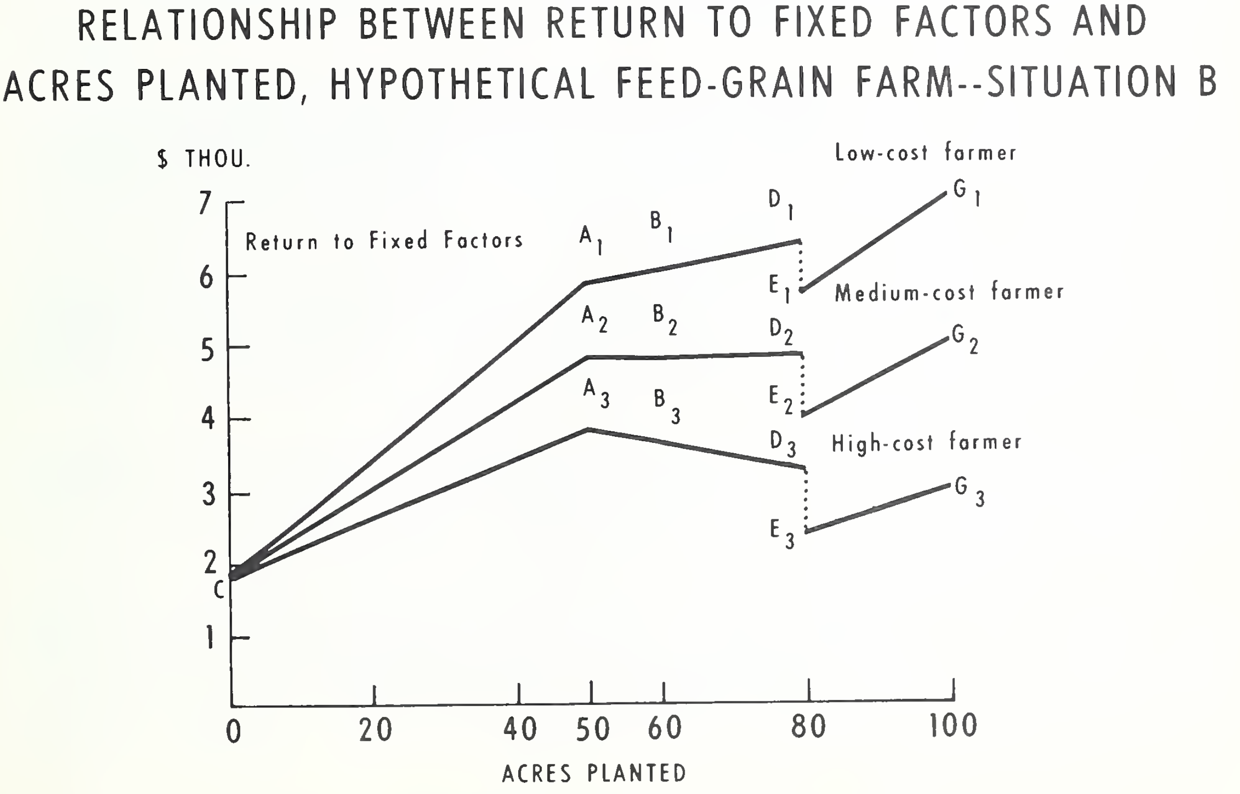
DASHED LINES INDICATE REVENUE COMPONENTS AND THE DOTTED LINE IS A DISCONTINUOUS FUNCTION.

Figure 3

Summary of Theoretical Effects

Examination of the above models indicates that four factors affect the number of farms participating and the level of participation. First, the expected level of the market price relative to the support rate would affect the number of farmers participating. Second, the payment rate for required diversion (by also varying MT in fig. 1) would have a similar effect. Third, payment rates for diversion of between 20 and 40 percent of the base and between 40 and 50 percent of the base would affect level of participation, as well as rate. Finally, different farmers respond differently to the same program because of different variable-cost levels.

Raising payment rates for diversion or raising the total support rate would both increase diversion. Given a set of program provisions such as those specified in figures 3 and 4, with market price at $1.10 (total revenue QRPSTU), a change in any one provision would affect the low-, medium-, and high-cost farms differently. An increase in payment for over 40 percent of base diverted would most likely cause the medium-cost farmer to switch from nonparticipation to participation at the maximum; lowering this diversion payment rate would likely cause the high-cost producer to produce at B_3 rather than A_3. It would take, in this example, a large increase in the support rate or payment for required diversion, or both, to entice the low-cost producer into the program. Since the remainder of this report deals with aggregates of farms, one would expect that a change in any of the above mentioned provisions could elicit a change in diversion.


RELATIONSHIP BETWEEN RETURN TO FIXED FACTORS AND ACRES PLANTED, HYPOTHETICAL FEED-GRAIN FARM--SITUATION B

DOTTED LINES ARE DISCONTINUOUS FUNCTIONS.

Figure 4

The Preliminary State Models

The hypothetical farm models suggest that several provisions of the feed-grain program affect producer response and that different groups of producers may react differently to a specific provision. Least-squares multiple-regression techniques were used to estimate the aggregate response of large groups of producers to changes in specified provisions of the feed-grain program. The regression models were formed largely from the variables discussed in the analysis of hypothetical farms.

States were chosen as the appropriate aggregative units, since data are readily available by State for the entire experience of the feed-grain program and because producers in different geographic regions were expected to respond differently. In the preliminary analysis, States in the North Central and Great Plains areas were considered. They are: Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, Wisconsin, Colorado, Kansas, Nebraska, North Dakota, South Dakota, and Wyoming.5/ Regression models used for each State in the preliminary analysis are defined in appendix B as model I. Only 8 years of data were used since this stage of the study was done early in 1969, before data for 1969 diversion were available.

Variables Used

Y -- the dependent variable--is total acres of cropland diverted under the program including both required diversion and optional diversion (expressed in thousands of acres).

X_1 -- the payment rate for the minimum 20-percent required diversion--is the product of the proportion of normal production used in determining the diversion payment and the total support rate for corn (in cents per bushel). (Support rates for barley and grain sorghum vary nearly identically with the rate for corn.)

X_2 -- the payment rate for diversion of 20 to 40 percent of the base--is the product of the total support rate for corn (cents per bushel) and the proportion of normal or projected production used for computing the diversion payment.

X_3 -- the payment rate for diversion exceeding 40 percent of the base--is computed as the product of the total support rate for corn (cents per bushel) and the proportion of normal production used for computation.

X_4 -- the difference between expected market price and total support rate. The January 15th market price series was used as a proxy for the expected market price. This series is not uniform among corn, grain sorghum, and barley. Since only corn and grain sorghum are consistently included in the program, the series for one or the other was used for each State; the

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5/ These 2 areas correspond to those being used in policy analysis work in the Farm Production Economics Division (FPED), ERS, USDA.

series used depended on the relative importance of the respective grains in that State. The unit of measurement was cents per bushel (for corn) or cents per hundredweight (for grain sorghum).

X_5 -- the maximum percentage of the base that may be diverted under the program.

X_6 -- a dummy variable having the value of one when barley is included and the value of zero when barley is excluded. Obviously, the allowed diversion is not the same when the barley base is included (1962-66 and 1969) as when it is excluded (1961, 1967, and 1968). The coefficient b_6 would be added to b_o when barley is included, which adjusts for the increase in mean diversion in those years.

X_7 -- the maximum diversion allowed--is the product of X_5 and total base allocated to all feed grains for the year (in thousands of acres). This variable includes the adjustment for barley, since the total base is enlarged when barley is included in the program, and this variable also adjusts for any autonomous changes in the amount of base.

X_8 -- a dummy variable to measure the linear time trend. For 1961, X_8 equals 1; for 1962, X_8 equals 2; and so on. From examination of the data, it is clear that time, the total support level, and the change from normal to projected production are highly intercorrelated. Hence, X_8 was used as a proxy for the whole set of variables associated with time changes.

Results

The regression procedure considered all combinations of two or more of the above variables for each State. Consistent with the first goal of identifying all significant relationships, the equation chosen for each State included the largest number of variables, subject to the condition that the partial F-ratio for each variable was significant at the $\alpha = .10$ level.[6] When nonsignificant variables were found, the equations were re-estimated without these variables. Results of these equations are reported in table 1. Variables appear in the table in order of their overall significance.

The X_7 variable, which shows maximum diversion in acres, is superior to X_5, which shows maximum diversion in percentage whether or not X_5 was used with X_6. Furthermore, X_7 is significant in every case, perhaps because of the universal decline in diversion in 1967, when the maximum was less than half that in 1966 and 1968. Therefore, X_5 and X_6 are never better than X_7 and hence were not included in table 1. For example, in Nebraska, b_7 indicates that for every 1,000 acres of possible diversion, 546 acres were actually diverted. F_7 indicates that there is less than one chance in 100 that X_7 and Y are not functionally related, given the other variables in the Nebraska equation.

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[6] The explanation of the partial F-test (F') is given in app. B.

Table 1.--Results of regression equations for preliminary State models, feed-grain diversion, 1961-68

State	Constant b_o	Independent variables										$s_{y.x}$	F_t
		Maximum diversion		Time		Payment for 2d 20-percent diversion		Payment for 50-percent diversion		Square of price difference			
		b_7	F_7	b_8	F_8	b_2	F_2	b_3	F_3	b_4	F_4		
North Dakota	-3,412	0.509	325.3**	92.7	47.2*	38.0	28.8*	4.33	43.4*	0.21	16.2	39.3	251.9**
South Dakota	-282	0.391	60.3**	94.4	49.4**	0	NA	0	NA	0	NA	83.8	43.4**
Nebraska	-5,991	0.546	1,773**	115.8	351.4**	75.2	316.7**	6.96	266**	0.174	69.9*	26.0	595**
Kansas	-6,370	0.433	26.7*	97.6	6.2	82.9	9.8	7.98	9.5	0.385	9.12	158.4	9.0
Wyoming	-0.42	0.297	92.9**	1.2	5.4	0	NA	0	NA	0	NA	3.4	47.2**
Colorado	102	0.417	29.7**	0	NA	0	NA	0	NA	0	NA	68.3	29.7**
Minnesota	-2,114	0.467	492**	102.9	136**	29.8	24.4**	0	NA	0	NA	38.5	286**
Iowa	-6,352	0.422	80.9*	127.5	20.4*	84.8	18.4	6.99	11.7	0.621	9.3	121.6	35.2*
Missouri	-3,332	0.565	60.4**	44.5	5.1	54.5	16.0*	0	NA	0	NA	87.7	21.5**
Wisconsin	227	0.292	38.9**	19.3	8.9*	0	NA	0	NA	0	NA	41.9	25.4**
Illinois	-3,780	0.204	57.6**	0	NA	60.9	91.8**	2.77	8.7	0.742	59.3**	59.0	59.9**
Indiana	618	0.214	11.0*	0	NA	0	NA	0	NA	0.315	6.3	100.2	11.1*
Michigan	-1,357	0.420	72.1**	55.5	105.8**	20.2	30.9**	0	NA	0	NA	23.9	51.8**
Ohio	-2,401	0.401	12.9*	50.0	6.4	35.9	6.8	0	NA	0	NA	93.8	4.6

Note: All F-ratios are significant at the $\alpha = 0.10$ level except for Kansas, where F_8 and F_t are nearly significant at this level. -'s indicate variables were omitted because they were nonsignificant. * = Significant at the $\alpha = 0.05$ level; ** = Significant at the $\alpha = 0.01$ level. NA means not applicable.

X_8, as a proxy for variables associated with time changes, was nearly always significant with a positive coefficient. This significance indicates that diversion has increased over time, given the effects of the other variables in the model. For example, in Nebraska, b_8 indicates that diversion has increased by 115,800 acres per year; F_8 shows that this relationship was significant at the 1-percent level. Unfortunately, X_8 and the payment rate for the first 20-percent required diversion, X_1, were highly intercorrelated. Statistical techniques used make it impractical to include in any single model two variables that are highly intercorrelated. Hence, X_1 was not included in any of the models in table 1; to the extent that the effects of X_1 are linear, they are accounted for by X_8.

The payment variables (X_2 and X_3) were not so universally important but were significant in several States. For example, in Nebraska, b_2 indicates that an increase in payment for the second 20-percent diversion of 1 cent per bushel of corn-equivalent (normal or projected yield) will result in an increase of 75,200 acres of diversion; and b_3 shows that a 1-cent increase in payment for 40- to 50-percent diversion will bring about a 6,960-acre increase in diversion. F_2 and F_3 each indicate that, for Nebraska, these relationships are significant at the 1-percent level.

The price difference variable (X_4) was not significant in half the States, but was useful in others. In its pure form, as described previously, this variable was almost never significant. However, when squared, X_4 was more significant. One explanation is that farmers respond relatively more to a large price difference than to a small one. For Nebraska, b_4 indicates that an increase of 1 cent per bushel in the square of the difference between the expected market price for corn and the announced total support rate would yield a 174-acre increase in diversion; F_4 shows that there is less than one chance in 20 that the relationship is a chance occurrence.

For an evaluation of the overall equations, $s_{y.x}$ and F_t are shown in table 1 as they are defined in appendix B. For Nebraska, $s_{y.x}$ shows that the "average" error of estimates with this equation is 26,000 acres of diversion; F_t shows that there is a greater-than-99-percent probability that a real relationship exists between the included variables.

COMPREHENSIVE ANALYSES

The Pooled Model

Based on results of the theoretical analysis and the preliminary State models, a more comprehensive analysis was undertaken. First, it was observed that the significant b_j coefficients reported in table 1 are somewhat similar in magnitude in the respective States. For example, b_7 ranges from 0.204 in Illinois to 0.565 in Missouri; b_2, from 20.2 in Michigan to 84.8 in Iowa. If the true functional relationships were similar for the several States, a pooled model could be used. Such a model would help to solve the problem of insufficient data that exists in the State models. For example, in the preliminary State model for Nebraska shown in table 1, the partial F-test for each b_j had only 2 degrees of freedom for error. With so few observations, it was very difficult to obtain F-ratios that were significant, even though the coefficients may have been similar to those in other States. In completing the preliminary State equations, it was assumed that the 8 years of data were sampled from a larger population of years. For the pooled model, it was hypothesized that the population was over all States and time. Then each year's experience in any one State could be considered a single observation, and the data could be pooled using a model similar to model II in appendix B.

At the time this pooled model was estimated, data concerning the sign-up for the 1969 feed-grain program were available. Some "slippage" was expected between intended diversion and actual diversion in 1969, as such slippage had occurred in the past. In 1968, actual diversion was 4 percent below intended diversion, and this same percentage was used to deflate 1969 intended diversion. Even though there was some error in this adjustment, it was felt to be outweighed by the gain in number of observations, particularly by the gain in observations on the number of years in which the program included barley.

It is obvious that State aggregates of farms do not, in fact, respond uniformly to all of the variables defined above. It is also clear that at least some of the differences are results of measurable economic and geographic differences. For the pooled model, more sophisticated variables were created to measure these differences and to more accurately estimate relationships identified in the preliminary analysis.

Variables Used

Y -- diversion, the dependent variable--is defined as total diversion divided by total base acreage. This change from the definition used in the State equations was made for two reasons that presented difficulties. First, it seems theoretically more accurate to expect a change in, say, a payment rate, to affect the portion of base diverted rather than acres diverted--especially when the base changes over time with the inclusion or exclusion of barley as a feed grain. Second, to compare the effect of a change in, say, payment rates in a large State with the effect in a small State, it is necessary to adjust for the size of the State. Defining Y as the portion of total base diverted avoids these difficulties.

X_1 -- the dummy variable for time--was left unchanged from the preliminary State equations.

X_2 -- the maximum diversion variable--was changed in two ways from its form in the State models. First, since Y was expressed as a ratio for the pooled model, maximum diversion was also expressed as a ratio in the pooled model--similar to the maximum diversion (percentage) considered before. Second, since the proportion of base on small farms varies among States, and since maximum-diversion restriction applies only to large farms, X_2 was adjusted to allow for the varying importance of large farms. For simplicity, farms were classified as small (less than 26 acres of base) or large (26 acres or more).[7] The formula for adjustment was:

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[7] This simplification ignores the special provisions for farms with base of 26-125 acres.

$$X_2 = \begin{bmatrix}\text{maximum proportion} \\ \text{of diversion allowed} \\ \text{on large farms}\end{bmatrix} \times \begin{bmatrix}\text{proportion of} \\ \text{base on large} \\ \text{farms in 1964}\end{bmatrix} + \begin{bmatrix}\text{proportion of} \\ \text{base on small} \\ \text{farms in 1964}\end{bmatrix}$$

Although the relative importance of large and small farms may vary over time within any State, it was assumed that such changes were insignificant or so gradual, or both, that the time variable would account for the change. Therefore, the 1964 proportion was used to adjust all years.

X_3 -- the payment rate for the second 20 percent of the base diverted--was left unchanged except that it was expressed as dollars per bushel of corn-equivalent (normal or projected production) rather than cents per bushel.

X_4 -- the payment rate for diversion of 40 to 50 percent of the base--was also changed to dollars per bushel of corn-equivalent (normal or projected production) rather than cents per bushel.

X_5 -- the price difference variable--was extensively modified. To account for the average effect of differences in prices of corn, grain sorghum, and barley, a weighted average price difference was constructed. Weights for corn, grain sorghum, and barley prices were the proportions of total feed-grain base made up of corn, grain sorghum, and barley, respectively, in the State in the year. To combine the three series, a common unit of measure was necessary. It was hypothesized that proportional price differences rather than absolute differences should be weighted; hence, total support rate minus market price for a grain in ith year divided by total support rate in 1964 for that grain was used. For barley, this price difference was sometimes negative, which reflects higher market prices resulting from the greater distance of markets from harvest areas; hence, 0.10 was added to each barley ratio. Thus, the value of X_5 in the ith year for the kth State or region is given by:

$$X_{i5k} = J_{ik} \frac{B_i - A_i}{B_4} + K_{ik} \frac{D_i - C_i}{D_4} + L_{ik} \left[\frac{(F_i - E_i)}{F_4} + 0.10 \right]$$

where

J_{ik} is the proportion the corn base constitutes of total base allocated to all farms in the kth State or region in the ith year (thousands of acres): $i = 1, 2, \ldots, 9$; and $k = 1, 2, \ldots, 23$;

K_{ik} is the proportion the grain sorghum base constitutes of total base allocated to all farms in the kth State or region in the ith year (thousands of acres);

L_{ik} is the proportion the barley base constitutes of total base allocated to all farms in the kth State or region in the ith year (thousands of acres); and

A_i, C_i, and E_i measure the January 15th market price for corn (cents per bushel), grain sorghum (cents per hundredweight), and barley (cents per bushel), respectively, in the i^{th} year; while

B_i, D_i, and F_i measure the announced total support rate for corn (cents per bushel), grain sorghum (cents per hundredweight), and barley (cents per bushel), respectively, in the i^{th} year.

X_5 is probably most important to the cash-grain producer. Since the livestock producer must risk delivering his grain to the CCC and buying other feed to take direct advantage of the difference between expected market price and the loan rate, only very large differences are likely to be important to him. To account for this relationship, an alternative, weighted form of X_5 was evaluated:

$$X'_{i5k} = X_{i5k} \left[\frac{C_k}{T_k} \right]$$

where

C_k is acres of corn, sorghum, and barley harvested for grain on cash-grain farms in 1964 in the k^{th} State or region, and

T_k is total acres of corn, sorghum, and barley harvested for grain on commercial farms in 1964 in the k^{th} State or region.

It was also hypothesized that price difference may be more important to large farms than to small farms. A third form of the X_5 variable was weighted by the portion of feed-grain base on large farms, as in X_2:

$$X''_{i5k} = X_{i5k} \left[\frac{C_k}{T_k} \right] H_k$$

where

H_k is total base allocated to all farms with base of 26 acres or more divided by total base allocated to all feed grains for all farms in the k^{th} State or region in 1964.

Intermediate analyses determined that X''_{i5k} explained a higher percentage of the variation in diversion than either X_{i5k} or X'_{i5k}. Thus, X''_{i5k} is the form reported below.

Diverted acreages under feed-grain programs, as well as bases for the respective feed grains, are found in USDA publications (4, 7, 8, and 9).[8] Selected data components of the variables are presented in tables 12, 13, and 14 in appendix C.

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[8] Published figures for diversion in 1966 and 1967 include only the acreage diverted for payment. Total diversion was computed for this study using information contained in the summary statistics for each State (7 and 8).

In the pooled model, it was hypothesized that coefficients (b_j: $j = 1, 2, \ldots, 5$) for the variables discussed in this section would not be significantly different among the various States and regions. In terms of appendix model II, $p = 5$. To allow for differing means among the States and regions, dummy variables (X_j: $j = 6, 7, \ldots, 27$) were added which are consistent with the last term of model II; that is, $m = 23$. Additional States were included in the pooled model in the hope that a more complete set of data might yield more meaningful results. Besides the Great Plains and North Central States, each South Central State was included--Arkansas, Louisiana, Mississippi, Oklahoma, and Texas. Since no other single State produces a relatively large quantity of feed grains, other areas of the United States were aggregated into four regions.[9]

1. Northwest: Idaho, Montana, Oregon, Utah, and Washington;
2. Southwest: Arizona, California, Nevada, and New Mexico;
3. Northeast: Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont;
4. Southeast: Alabama, Florida, Georgia, Kentucky, North Carolina, South Carolina, Tennessee, Virginia, and West Virginia.

Results

Independent variables X_1-X_{27} were regressed on the dependent variable Y. The resulting b_j's are shown in table 2.[10] The pooled prediction equation is:

$$\hat{Y}_{ik} = -0.56389 + 0.01367\ X_{i1k} + 0.39238\ X_{i2k} + 0.75067\ X_{i3k} + 0.03557\ X_{i4k} + 0.73253\ X''_{i5k} + b_{k+5}$$

To obtain the intercept term for, say, Iowa ($k = 9$), b_o was added to b_{14} (9 + 5), as indicated in appendix model II. The various intercept terms are expressed as the ratios of acres diverted to conserving use, to the total base allocated to all feed grains (the proportion of base diverted). Interpretation of the first four regression coefficients is straightforward. The value 0.01367 for b_1 indicates that after other variables (X_2 through X_{27})

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[9] These additional regions also conform to the regions being used in the policy analysis of FPED, ERS, USDA.

[10] Possibly, the pooled model violates the statistical assumption of random independent errors. Technical aspects of this assumption for model II are discussed in app. B. For the pooled model, this problem could develop to the extent that an exogenous and omitted variable (say, cattle prices) would affect the response in all States in a given year. In such cases, the b_j estimates would remain unbiased but would be less accurate than is suggested by the partial F-ratios.

Table 2.--Values and significance of coefficients in the pooled model

	Variable	b_j	F'	R_k^2
	Intercept (Southeast)	-.56389	NA	0.62
X_1	Time	.01367	110.14**	NA
X_2	Maximum diversion	.39238	125.81**	NA
X_3	Payment for second 20-percent diversion	.75067	58.95**	NA
X_4	Payment for 50-percent diversion	.03557	16.05**	NA
X_5''	Price difference	.73253	43.34**	NA
X_6	Colorado	.00036	.01	.76
X_7	Kansas	-.01354	.59	.56
X_8	Nebraska	.01476	.73	.76
X_9	North Dakota	-.00235	.02	.62
X_{10}	South Dakota	-.01312	.65	.85
X_{11}	Wyoming	-.07576	24.63**	.47
X_{12}	Illinois	-.11823	42.94**	.22
X_{13}	Indiana	-.05491	11.75**	.92
X_{14}	Iowa	-.00429	.07	.94
X_{15}	Michigan	-.01283	.81	.72
X_{16}	Minnesota	.00223	.02	.83
X_{17}	Missouri	.05614	12.94**	.78
X_{18}	Ohio	-.06398	19.09**	.86
X_{19}	Wisconsin	-.04309	9.27**	.56
X_{20}	Arkansas	-.10703	55.81**	.07
X_{21}	Louisiana	-.09232	41.03**	.25
X_{22}	Mississippi	-.01283	.80	.41
X_{23}	Oklahoma	-.03558	4.71*	.07
X_{24}	Texas	.01948	1.51	.73
X_{25}	Northwest	-.09926	31.88**	.25
X_{26}	Southwest	-.03265	3.93*	.58
X_{27}	Northeast	-.11721	68.60**	.85

Note: * = significant at the α = .05 level; ** = significant at the α = .005 level. NA means not applicable.

have been accounted for, there has been an increased diversion of 1.367 percent of the base each year from 1961 to 1969. The coefficient of X_2 is 0.39238. This coefficient indicates that for each additional 10 percent of base that farmers were allowed to divert, actual diversion increased by 3.9238 percent of the base. Interpretation of b_3 (0.75067) is that for a 1-cent-per-bushel-increase in the corn-equivalent payment rate for diversion of 20 to 40 percent of base, actual diversion increased by 0.75067 percent of base. The coefficient for X_4 is 0.03557; as the payment rate for diversion of over 40 percent of base increased by 1-cent-per-bushel corn-equivalent, diversion increased by 0.03557 percent of the base.

Interpreting b_5 is less direct. Intuitively, b_5 (0.73253) indicates that as the weighted price difference increased by 1 percent of the 1964 support rate, diversion increased by 0.73253 percent of the base. For example, consider a State with no base except for corn. If the total support rate for corn was \$1.30 per bushel for 2 years and the expected market price was \$1.25 the first year and \$1 the next year, the price difference would increase 25 cents, or 20 percent of the 1964 support rate of \$1.25 per bushel. Assume that 70 percent of feed grains were grown on cash-grain farms in that State (in 1964) and that 70 percent of the base was allocated to farms with more than 26 acres of base (in 1964) in that State. Then, the change in the value of X''_5 would be $\frac{.25}{1.25} \times .7 \times .7$, or approximately 0.10. Thus, if the total base allocated to all feed grains (corn) in that State was 1 million acres in both years, there would have been an increase of (1 million x .10 x 0.73253) 73,253 acres of diversion because of the decrease of 25 cents per bushel in the January 15th market price of corn.

Note that the coefficients b_1-b_5 in table 2 apply to all States and regions. Differences in mean diversion are accounted for by the pooled model in two ways:

1. Components of X_2 and X''_5 that are constant over time for a State account for variation that is related to these variables; and
2. Dummy variables X_6-X_{27} account for any additional differences in average responses of the States.

This interaction should be considered when evaluating the importance of X_2 and X''_5.

The partial F-ratios (F') for testing the hypothesis H_o: $B_j = 0$ for each coefficient are shown in table 2. Each of these F-ratios has 1 degree of freedom for regression and 179 degress of freedom for error; that is, m (n-1) - p in table 10 of appendix B. All five program variables are significant at the $\alpha = 0.005$-level, and 12 of the intercept terms are significant at the $\alpha = 0.05$-level or better. The last column of the table shows the coefficients of multiple determination, R^2_k, as defined in appendix B. These values show the proportion of variation within each State or region that is explained by the regression equation. These values range from a high of 0.94 in Iowa to a low of 0.07 in Oklahoma. The Corn Belt and Great Plains States generally exhibit coefficients in the 0.50-0.90-range.

The analysis-of-variance table for the pooled model is given in table 3 (equivalent to table 10 in app. B). From the F_t for regression, including all variables, it is clear that the explanation provided by the pooled model is not likely a chance occurrence since $F_t = 25.4$, compared with a critical value of $F^{.005}_{27,179} = 2.05$. Thus, we reject H_o: $B_1 = B_2 = \ldots = B_{27} = 0$. After the means of all States have been accounted for, addition of b_1-b_5 to the pooled model is significant in table 3, with $F = 59.8$, compared with a critical value of $F^{.005}_{5,179} = 3.45$. Thus, we reject H_o: $B_1 = B_2 = \ldots = B_5 = 0$.

Possibly, the unexplained variation is concentrated in those States whose feed-grain production is incidental. To adjust for this possibility, the sum of squares for each State was weighted by the mean total base allocated to all feed grains for that State:

$$TSS = \sum_{i=1}^{n} \sum_{k=1}^{m} \left[(Y_{ik} - \overline{Y}_k)(\overline{B}_k)\right]^2$$

where $\overline{B}_k$ is the mean total base allocated to all feed grains in the k^{th} State or region (thousands of acres). Table 4 presents the analysis of variance when this weighting is used. Apparently, the fit is better for States with larger bases since $F = 86.1$, compared with 59.8 for the unweighted results. These results indicate that an appreciable portion of the unexplained variation was due to the equal weighting of States in the pooled model (table 3).

The Final State Models

The pooled model identifies several independent variables that have a significant effect on the proportion of feed-grain base diverted. These variables were next used to estimate a set of 23 equations, defined in appendix model III. Experience with the preliminary State models suggested that it might be best to allow some b_{jk}'s to be zero; that is, some X_{jk}'s might not be significant explanatory variables for some States. The final State models were thus estimated for each State and region subject to these criteria:

1. The variables used were in the same form as in the pooled model.
2. All combinations of these variables were estimated. The combination associated with the lowest standard error of estimate $s_{y.x}$ was chosen for each State.
3. All coefficients with a negative sign and for which the F_{jk} was not significant at $\alpha = .05$ were assumed to be zero and the equation was re-estimated without those variables.

Table 5 shows the regression equations for these State models. Interpretation of the coefficients is similar to interpretation of those in the pooled model since the same variables were used. Examination of table 5 shows that the variables used to explain diversion perform quite well. The North Central and Great Plains areas are very well explained. The Southern States and regions (Louisiana, Arkansas, and the Southeast) show no significant response to X_3, X_4, or X_5''. Arkansas with R^2_k of .46 and Louisiana with R^2_k of .14 do not fit the

Table 3.--Analysis of variance for pooled model

Source	Sum of squares	Degrees of freedom	Mean squares	F-ratio
Total (corrected for b_o)	.779	206	NA	NA
Regression (X_1-X_{27})	.619	27	.0229	25.4**
Residual	.160	179	.0009	NA
Total (corrected for b_o, b_6-b_{27})	.429	184	NA	NA
Regression (X_1-X_5)	.269	5	.0538	59.8**
Residual	.160	179	.0009	NA

Note: ** = significant at the α = .005 level. NA means not applicable.

Table 4.--Analysis of variance for pooled model, weighted by average base

Source	Sum of squares	Degrees of freedom	Mean squares	F-ratio
Total (corrected for b_o, b_6-b_{27})	20,376,397	184	NA	NA
Regression (X_1-X_5)	14,391,029	5	2,878,206	86.1**
Residual	5,985,370	179	33,438	NA

Note: ** = significant at the α = .005 level. NA means not applicable.

Table 5.--Results of regression equations for final State models, feed-grain diversion, 1961-69

State or region	k	Estimated coefficients											$s_{y.x}$	F_{tk}	R^2_k
		Con- stant--	Time		Maximum diversion		Payment for 2d 20-percent diversion		Payment for 50-percent diversion		Price difference				
		b_o+b_{5+k}	b_{1k}	F_{1k}	b_{2k}	F_{2k}	b_{3k}	F_{3k}	b_{4k}	F_{4k}	b_{5k}	F_{5k}			
Colo.	1	-1.1141	.0182	11.6*	.5693	22.79*	1.2603	9.52†	.1095	7.51†	1.6887	9.52†	.0248	8.83†	.94
Kans.	2	-.9157	.0108	3.61	.4322	10.48*	1.1573	7.32†	.0969	4.20	.9139	4.29	.0267	3.86	.87
Nebr.	3	-.6623	.0114	28.96*	.5292	109.41**	.8432	28.29*	.0696	16.10*	.3548	3.06	.0097	43.97**	.99
N. Dak.	4	-1.6065	.0363	85.52**	.2208	7.07†	2.1226	46.36**	.1004	17.28*	1.2571	72.00**	.0174	27.28*	.98
S. Dak.	5	-.4496	.0174	23.94**	.4622	25.72**	.5351	4.00	0	NA	.4936	1.16	.0185	17.91**	.95
Wyo.	6	-.3321	.0120	5.83†	.1160	.52	.5350	2.02	0	NA	.8989	1.33	.0330	2.31	.70
Ill.	7	-.3887	.0027	.71	.2681	8.59*	.5444	4.86†	0	NA	.5069	10.36*	.0171	7.26*	.88
Ind.	8	-.5872	.0109	14.77*	.3614	18.55*	.7297	11.73*	.0315	1.99	.7844	14.97*	.0130	14.9*	.96
Iowa	9	-.5382	.0104	51.89**	.4302	144.09**	.6782	38.94**	.0540	22.30*	.7439	18.84*	.0066	73.41**	.99
Mich.	10	-.8458	.0240	145.05**	.6561	75.14**	.9022	36.28**	0	NA	0	NA	.0104	75.00**	.98
Minn.	11	-.3782	.0159	53.06**	.5025	72.61**	.4556	7.73*	0	NA	.2291	1.56	.0113	47.32**	.98
Mo.	12	-.7816	.0091	9.21*	.6817	56.33**	1.0452	21.27**	0	NA	.2810	1.53	.0156	17.61**	.95
Ohio	13	-.7968	.0157	22.88**	.5164	18.36*	.9193	13.87*	0	NA	.5227	4.72†	.0171	11.41*	.92
Wis.	14	-.0495	.0051	12.99*	.4095	49.99**	0	NA	0	NA	0	NA	.0110	35.64**	.92
Ark.	15	-.3251	.0080	3.88	.2549	1.66	.4791	2.47	0	NA	0	NA	.0211	1.41	.46
La.	16	-.0336	0	NA	.3574	1.18	0	NA	0	NA	0	NA	.0440	1.18	.14
Miss.	17	-.0186	.0187	18.08**	.3094	1.71	0	NA	0	NA	0	NA	.0338	10.36*	.78
Okla.	18	-.4048	.0043	.99	.3353	7.56†	.6530	4.02	0	NA	.2943	1.32	.0225	2.28	.70
Tex.	19	-.8458	.0125	18.39**	.7061	86.72**	1.0805	24.32**	0	NA	0	NA	.0152	30.83**	.95
N.W.	20	-.7180	.0197	18.87*	.0009	.01	1.0824	9.31*	0	NA	.9520	29.04**	.0228	10.41*	.91
S.W.	21	-.9219	.0091	16.35*	.5938	116.71**	1.1598	46.53**	0	NA	1.1581	26.21**	.0117	33.21**	.97
N.E.	22	-.2974	.0104	123.42**	.2703	49.62**	.3337	22.19*	.0213	8.70†	.3859	7.81†	.0043	58.24**	.99
S.E.	23	-.0586	.0131	19.72**	.4330	10.96*	0	NA	0	NA	0	NA	.0227	17.68**	.86

Note: † = Significant at the ∝ = 0.10 level; * = Significant at the ∝ = 0.05 level; and ** = Significant at the ∝ = 0.01 level.
NA means not applicable.

model well because cotton and rice farms perhaps do not respond like cash-grain or livestock farms. Nevertheless, the errors are small in all States; Louisiana with $s_{y.x} = .044$ (4.4 percent of base) was the highest.

The unweighted and weighted analysis of variance is shown in tables 6 and 7; the components of these tables are defined in table 11 of appendix B. Tables 6 and 7 test the hypothesis that all of the parameters--b_{jk}'s for $j = 1, 2, \dots, 5$ and $k = 1, 2, \dots, 23$--are equal to zero. Again, the F_t-ratios are highly significant, with the highest being achieved when the components of variation are weighted by the average base (table 7). These tests in tables 6 and 7 include all of the coefficients of the States and regions.[11] Table 5 shows the F_{tk}-ratios that test the significance of each State or regional model when considered by itself.

Comparing the pooled model and the final State models shows that the latter explain a greater portion of variation. The regression sum of squares (unweighted) in table 6 is 0.395, compared with 0.269 in table 3 for the pooled model. The partial F-ratio, testing the significance of the added, separate coefficients for each State and region as discussed in appendix B is:

$$F'' = \frac{(.395 - .269)/110}{.00049} = 2.34$$

The partial F-ratio for the weighted analysis of variance is:

$$F'' = \frac{(19,285,265 - 14,391,029)/110}{15,814} = 2.81$$

Both of these ratios are significant at $\alpha = .01$, and the hypothesis that the additional coefficients in the final State models (model III) are not significant is rejected. These tests suggest that the separate coefficients included in the final State models offer a more accurate description of the factors affecting diversion than do those of the pooled model.

Estimation of Total U.S. Diversion in 1969

The coefficients presented in table 5 provide a basis for estimating total U.S. diversion for specified feed-grain programs, as long as these programs can be defined in terms of the variables used in the final State models. For example, consider estimating the diversion that would be expected under the 1969 program, based on results presented in table 5. This exercise provides an example of the models' capabilities for estimating total U.S. diversion for a specific year.

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[11] Technically, the analysis of variance presented in tables 6 and 7 does not pertain exactly to the models presented in table 5. Tables 6 and 7 present the variance components when all mp = 115 variables are included, while in table 5, several of the States and regions contain less-than-p variables. This discrepancy is necessary for the computational procedures used and because of the desire to compare the pooled model and the final State models. It does not significantly bias the F_t-tests of tables 6 and 7 or the F''-tests.

Table 6.--Analysis of variance for final State models

Source	Sum of squares	Degrees of freedom	Mean squares	F-ratio
Total (corrected for b_o, b_6-b_{27}	.429	184	NA	NA
Regression (X_{1k}-X_{5k})	.395	115	.00343	7.0**
Residual	.034	69	.00049	NA

Note: ** = Significant at the $\alpha = 0.005$ level. NA means not applicable.

Table 7.--Analysis of variance for final State models, weighted by average base

Source	Sum of squares	Degrees of freedom	Mean squares	F-ratio
Total (corrected for b_o, b_6-b_{27})	20,376,399	184	NA	NA
Regression (X_{1k}-X_{5k})	19,285,265	115	167,698	10.6**
Residual	1,091,134	69	15,814	NA

Note: ** = Significant at the $\alpha = 0.005$ level. NA means not applicable.

The values for the five independent variables for estimation of the 1969 program diversion are presented in table 8. In this case, X_1 takes the value of nine for all States and regions. X_2, representing maximum diversion allowed, was computed from data presented in table 12 and 13 and defined previously. The payment rate for the second 20-percent diversion, X_3, is 45 percent of \$1.35, or \$0.61 for all States--in 1969 X_4, the payment rate for diversion of over 40 percent of the base, is equal to X_3. The price difference variable, X_5'', was computed from data presented in tables 12, 13, and 14 and was defined previously in the discussion of the variables.

Products of independent variables X_1-X_5 presented in table 8 and b_{jk} coefficients in table 5 then provide an estimate of the proportion, $\hat{Y}_k$, of feed-grain base that is diverted in each State or region. These estimates, shown in table 8, may be converted into acreage by multiplying them by the total 1969 feed-grain base in each State or region (table 14). These acre estimates are shown as the last column of table 8: their sum is the model's estimate of 1969 feed-grain diversion--39,332,000 acres. This value compares to the 1969 actual diversion of 39,065,818 acres. Thus, for 1969, the model overestimated U.S. diversion by 266,182 acres, or less than 1 percent. This error is consistent with $s_{y.x}$-values presented in table 5.

LIMITATIONS

Inherent in the study reported on here, as in all statistical studies, are special dangers due to the phenomena analyzed. The value of the predictive models lies in their capacity to explain future phenomena. The time variable, X_1, is particularly ill-suited for this purpose because of its use as a proxy for several variables as explained below:

1. Farmer knowledge and acceptance of the program is probably a non-linear trend, such as a logarithmic function. As more experience is gained, the linear estimate may be less accurate.

2. The association between the linear time trend and payment for required diversion was closest after 7 years. By 1969, the association had deteriorated; we could expect the coefficient for time to be larger in the future.

3. Other variables, such as technological change, adjustment of normal yields, and weather cycles, could also invalidate the time coefficient if future patterns of change in the variables depart from the 1961-69 patterns.

Often, statistical predictions are reported without consideration of expected accuracy of estimated parameters. Such use of the models reported on here would be very hazardous. Standard-confidence intervals for regression predictions widen as the difference between X_{ij} and $\bar{X}_j$ increases. Thus, accuracy of a prediction based on the time variable, X_1, in years after 1969 decreases with each year of extrapolation. Similar deterioration of confidence can be expected as other variables deviate outside the range of observations used in estimation.

Table 8.--Example of using the final State models to estimate U.S. total diverted acreage, 1969

State or region	Independent variable					$\hat{Y}_k$	Estimated acres diverted
	X_1	X_2	X_3	X_4	X''_5		
							1,000 acres
Colorado	9	.520	.61	.61	.0807	.3176	776
Kansas	9	.530	.61	.61	.1102	.2763	2,611
Nebraska	9	.510	.61	.61	.0891	.2986	2,967
North Dakota	9	.515	.61	.61	.1822	.4190	2,593
South Dakota	9	.510	.61	.61	.0542	.2959	1,735
Wyoming	9	.555	.61	.61	.0540	.2152	49
Illinois	9	.545	.61	.61	.1282	.1788	1,969
Indiana	9	.595	.61	.61	.0945	.2644	1,523
Iowa	9	.515	.61	.61	.0683	.2744	3,733
Michigan	9	.685	.61	.61	.0459	.3700	869
Minnesota	9	.535	.61	.61	.0787	.3297	2,860
Missouri	9	.585	.61	.61	.0761	.3581	2,120
Ohio	9	.655	.61	.61	.0638	.2769	1,102
Wisconsin	9	.660	.61	.61	.0135	.2667	855
Arkansas	9	.755	.61	.61	.0245	.2316	137
Louisiana	9	.760	.61	.61	.0126	.2380	119
Mississippi	9	.745	.61	.61	.0112	.3802	533
Oklahoma	9	.575	.61	.61	.1016	.2549	798
Texas	9	.540	.61	.61	.0564	.3071	3,892
Northwest	9	.545	.61	.61	.1584	.2709	1,311
Southwest	9	.510	.61	.61	.0704	.2518	887
Northeast	9	.715	.61	.61	.0328	.2187	740
Southeast	9	.690	.61	.61	.0205	.3581	5,153
Total	-	-	-	-	-	-	39,332

Such warning is particularly applicable in the study reported on here since evidence indicates that the true relationships are not linear over their entire range. All the intercept terms in the final State models are negative; the implication is that if the trends were extended to the point at which all $X_{ijk} = 0$, then diversion would be less than zero. Since negative diversion is not consistent with our definition of diversion, it may be concluded that the estimates made here are linear estimates of a nonlinear relationship. Over a narrow range, difference between the estimates and true relationships is apparently small. However, errors may become extremely large when predictions are based on values of independent variables outside the range of experience reported here.

Aside from the dangers of extending the variables beyond the observations, a further limitation lies in the complexity of the variables. No variable directly reflects a single provision of the program: time is a proxy for several variables; maximum diversion is weighted by the importance of large and small farms; price difference is a function of 15 elements; and the dependent variable is a quotient of diversion divided by base. None of these complexities warrants loss of confidence in the model, but intuitive interpretation of effects of provisions can be difficult. Care must be taken that assumptions behind the variables are understood when the models are used.

Clearly, the models do not work well for the Southern States. It may be worthwhile to attempt to develop models applicable to these States, as well as reevaluate equations for some of the other States.

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APPENDIXES

A: Provisions of the Feed-Grain Program

The feed-grain program is a system of price-support activities and incentives for reducing production of corn, grain sorghum, and (sometimes) barley. When the first program was initiated in 1961, estimates were made of normal acreage and production on each farm from which reductions were to be made. Each farm was allocated a "base" acreage corresponding to 1959-60 average acreage of corn and grain sorghum. Barley acreage in 1959-60 was added to the total base in 1962-66 and 1969. The yield associated with the base acreage was established by counties, with a productivity index assigned to individual farms to adjust from the county average. The 1959-60 "normal" yield was used for the 1961-63 programs; 1959-62 yield was used in 1964 and 1965; and "projected" yield was substituted for "normal" yield after 1966.

The one feature of the feed-grain program left unchanged since 1961 is the availability of price support to participants. The basic feature of these price-support activities is the nonrecourse loan; however, a price-support "payment" was added in 1963. Unlike the support loan, which is paid after harvest and requires storage or delivery of stocks to the CCC or both, the price-support payment is made on the basis of normal or projected production after signup in the spring. The total support rate--the sum of the loan and the price-support payment--rose rather steadily from 1961 through 1969. The price-support payment has made up an increasing portion of total support over time.

Participation in the program is voluntary. To participate, a farmer must divert a specified portion of his base to an approved conservation use. The definition of an "approved conservation use" varies by State, but production of either cultivated crops or pasture is not generally allowed. The farmer receives payment for this diversion based on gross income for a portion of normal or projected production. Diversion payments are divided into these categories:

Payment for required diversion. A minimum diversion of 20 percent of the total base has consistently been required of participants. In 1961-65, payment was made for the 20-percent required diversion. In 1961 and 1962, this payment was the support rate for 50 percent of normal production. The 1963-65 payment was at the total support rate for 20 percent of normal production. Since 1965, there has been no payment for the 20-percent required diversion.

Payment for additional diversion up to 40 percent of the base. When participants elect to divert more than is required, they are paid in a manner similar to that for required diversion. In 1961 and 1962, payment was the support rate for 60 percent of normal production on acres diverted between 20 and 40 percent of the base. In 1963-67, payment was at the total support rate for 50 percent of normal or projected production. In 1968 and 1969, the payment was at the total support rate for 45 percent of projected production.

Payment for diversion exceeding 40 percent of the base. From 1961 through 1967, the payment for diversion of more than 40 percent of the base was at the total support rate for 50 percent of normal or projected production.

In 1968 and 1969, payment was at the total support rate for 45 percent of projected production. As an added incentive in 1964 and 1965, farmers who diverted more than 40 percent of their base were paid at the total support rate of 50 percent for their entire diversion.[1]

Maximum amounts of diversion have been established for participating farms of various sizes.

Small-base farms. Farms on which the total feed-grain base does not exceed 25 acres have been allowed to divert their entire base for payment.

Large-base farms. Maximum diversion on farms on which the total base exceeds 100 acres has varied greatly over the years of the program. In 1961 through 1963, large farms could divert only 40 percent of their base for payment. The limit was at 50 percent for all other years except 1967, when diversion under that year's program was limited to 20 percent of the base--the required diversion.

Other farms. In 1961-66, farms with bases of 26 to 100 acres were allowed to divert 20 acres plus 20 percent of the base, which made a relatively smooth transition from the 100-percent maximum on small-base farms to the 40- or 50-percent maximum on large-base farms. Since 1967, farmers with bases from 26 to 125 acres have had ". . .the option of temporarily reducing this base down to 25 acres and still [being] eligible for the small farm provision on condition that no. . . [feed grains] will be planted for harvest on the farm and the 25 acres are diverted to conserving use" (13).

Other provisions of the program are of some relevance to this report. Corn and grain sorghum are the major feed grains affected by the program. However, in all years except 1961, 1967, and 1968, barley was also classified as a feed grain. In 1962, the barley program was similar but separate, but from 1963 on, barley was included under the general program. Substitution of one feed grain for another has been permitted since 1965. Since 1966, farmers signing up for the wheat and feed-grain programs have had the option of growing wheat on feed-grain bases and feed grains on the wheat allotment.

B: Summary of Statistical Methods Used

Assumed for the study reported on here was a general linear model of the form:

$$Y_i = \sum_{j=0}^{p} B_j X_{ij} + e_i$$

where

Y_i is the value of the dependent variable in the i^{th} year:

$i = 1, 2, \ldots, n;$

---

[1] This paid, in effect, an additional 30 percent of normal production on the required diversion.

B_j is the population parameter (coefficient) associated with variable j: $j = 0, 1, 2, \ldots, p$;

X_{ij} is the value of independent variable j in the i^{th} year; and

e_i is the value of the random error associated with the i^{th} year and is assumed to be normally and independently distributed, with mean = 0 and variance = σ^2.

The corresponding prediction model may be written as:

$$\hat{Y}_i = b_o + \sum_{j=1}^{p} b_j X_{ij} \qquad \text{model I}$$

where

$\hat{Y}_i$ is the predicted value of the dependent variable in the i^{th} year, and

b_j is the estimate of B_j.

Estimates of variance and tests of significance may be made from the corresponding analysis-of-variance table, table 9. From this table, the mean square (MS) for the various components can be computed by dividing the sum of squares (SS) by the appropriate degrees of freedom; these mean squares form the basis for the various tests of hypotheses. For example, to determine whether a model has hit upon some relationship that is not likely to have been a random occurrence, a test of the null hypothesis H_o: $B_1 = B_2 = \ldots = B_p = 0$ is performed. The "F"-test is used and is denoted F_t to indicate the total or "overall" nature of its use here:

$$F_t = \frac{\text{Regression MS}}{\text{Residual MS}}$$

The critical value associated with the probability that the ratio could be a chance occurrence is found in the F-distribution for $F^{\alpha}_{p,\ n-p-1}$

where

α is the level of significance (the probability of a chance occurrence);

p denotes the degrees of freedom for regression; and

$n-p-1$ denotes the degrees of freedom for error.

If the calculated value of F_t exceeds the critical value at an appropriate significance level, the null hypothesis is rejected, and the alternative hypothesis that at least one B_j does not equal zero is accepted.

The standard error of the estimate; that is,

$$s_{y.x} = \sqrt{\frac{\sum_{i=1}^{n} (Y_i - \hat{Y}_i)^2}{n-p-1}}$$

Table 9.--Analysis of variance for model I

Source of variation	Sum of squares	Degrees of freedom
Total (uncorrected)	$\sum_{i=1}^{n} Y_i^2$	n
Total corrected for b_o	$\sum_{i=1}^{n} (Y_i - \bar{Y})^2$	n-1
Regression due to $X_1, X_2, \dots, X_p$	$\sum_{i=1}^{n} (\hat{Y}_i - \bar{Y})^2$	p
Regression due to $X_1, X_2, \dots, X_c$	$\sum_{i=1}^{n} (\hat{Y}'_i - \bar{Y})^2$	c
Regression due to $X_{c+1}, \dots, X_p$	$\sum_{i=1}^{n} (\hat{Y}_i - \bar{Y})^2 - \sum_{i=1}^{n} (\hat{Y}'_i - \bar{Y})^2$	p-c
Residual (error)	$\sum_{i=1}^{n} (Y_i - \hat{Y}_i)^2$	n-p-1

is of additional importance, since it is directly related to the average or expected error of estimates from the predictive equation. Another overall measure of any model's performance is the coefficient of multiple determination, which measures the portion of total variation explained by the model. This value is computed as:

$$R^2 = \frac{\text{Regression SS}}{\text{Total SS}}$$

The breakdown for a second test of hypotheses that is relevant to this report is also presented in table 9. Consider dividing the parameters into two sets such as $B_1, B_2, \dots, B_c, B_{c+1}, \dots, B_p$ and testing the hypothesis that the last p-c parameters equal zero. Then the appropriate partial F-ratio is:

$$F' = \frac{\dfrac{\begin{bmatrix}\text{Regression SS for} \\ X_1, X_2, \dots, X_p\end{bmatrix} - \begin{bmatrix}\text{Regression SS for} \\ X_1, X_2, \dots, X_c\end{bmatrix}}{p-c}}{\dfrac{\text{Residual SS for } X_1, X_2, \dots, X_p}{n-p-1}}$$

Inspection of table 9 shows that these statistics come from the third and fourth rows of the table, where $\hat{Y}'_i = b'_o + \sum_{j=1}^{c} b'_j X_{ij}$. An important, special case of this test is when p-c = 1; here we test the hypothesis that a specific $B_j = 0$.

The pooled model used in the study assumes that the dependent variable responds to changes in the independent variables similarly among respective sources of data but that the level of average response differs.

The general model assumed here is of the form:

$$Y_{ik} = \sum_{j=0}^{p} B_j X_{ijk} + \sum_{j=p+1}^{p+m-1} B_j X_{ijk} + e_{ik}$$

where

Y_{ik} is the value of the dependent variable in the i^{th} year for the k^{th} source; $i = 1, 2, \ldots, n$; $k = 1, 2, \ldots, m$;

B_j is the population parameter associated with the variable j; $j = 0, 1, 2, \ldots p+m-1$;

X_{ijk} is the value of the independent variable j for the i^{th} year and the k^{th} source; and

e_{ik} is the value of random error associated with the i^{th} year and the k^{th} source and is assumed to be normally and independently distributed with mean = 0 and variance = σ^2.[2]

This model includes m-1 dummy variables that identify the source of each observation. In general, X_{ijk} for $p < j \leq p+m-1$ takes the value one for $j = p+k$ and zero for $j \neq p+k$. Thus, for each source:

$$\sum_{j=p+1}^{p+m-1} B_j X_{ijk} = B_{p+k}$$

---

[2] The assumption that the e_{ik}'s are independently distributed warrants special attention. Under this assumption, each year's experience in each source is considered a single observation, and the data may be pooled. Degrees of freedom for error increased from n-p-1 in model I to m(n-1)-p, with similar increases in the significance of the estimated b_j. However, when the sources are States, there is a risk that some undefined and omitted variable will affect all e_{ik}'s similarly in a given year, which thus invalidates the assumption of independence. Although estimates of B_j will still be unbiased, the least-squares techniques used may seriously underestimate variances of these estimates. Thus, the F-tests used in this analysis are no longer valid, generally overstating the significance of the variables.

because

$$B_j X_{ijk} = \begin{cases} B_j & \text{when } j = p+k \\ 0 & \text{when } j \neq p+k \end{cases}$$

and these last m-1 B_j's are deviations in the average response of respective sources from the average response of the mth source, B_o.

The corresponding prediction model in this case is:

$$\hat{Y}_{ik} = b_o + \sum_{j=1}^{p} b_j X_{ijk} + \sum_{j=p+1}^{p+m-1} b_j X_{ijk} \qquad \text{model II}$$

where

$\hat{Y}_{ik}$ denotes the predicted value of the dependent variable in the ith year for the kth source;

b_j denotes the estimated coefficient of variable j; j = 1, 2, ... , p+m-1; and

b_o denotes the intercept term for the mth source.

Table 10 shows the relevant analysis-of-variance table for model II. Two basic tests of hypothesis may be made for this model: (1) the test that $B_1, B_2, \ldots, B_{p+m-1} = 0$ and (2) the test that the coefficients correspond to the real variables $B_1, B_2 \ldots, B_p = 0$. In the first test, only the overall mean is corrected for; in the second, the sum of squares is corrected for the overall mean and all of the source means.

The coefficients of multiple determination for the individual sources measure the portion of total variation within each source explained by:

$$R_k^2 = \frac{TSS_k - \sum_{i=1}^{n} (Y_{ik} - \hat{Y}_{ik})^2}{TSS_k}$$

where

R_k^2 is the coefficient of multiple determination for the kth source, and

TSS_k is the total sum of squares (corrected for $\bar{Y}_k$).

These coefficients may be computed from the bottom section of table 10.

Model III assumes that response to independent variables, as well as level of activity, may differ among sources. This model is:

$$\hat{Y}_{ik} = b_o + \sum_{j=1}^{p} b_{jk} X_{ijk} + \sum_{j=p+1}^{p+m-1} b_j X_{ijk} \qquad \text{model III}$$

Table 10.--Analysis-of-variance table for model II

Source of variation	Sum of squares	Degrees of freedom
Total (uncorrected)	$\sum_{i=1}^{n} \sum_{k=1}^{m} Y_{ik}^{2}$	nm
Test for all coefficients:		
Total corrected for b_o	$\sum_{i=1}^{n} \sum_{k=1}^{m} (Y_{ik} - \bar{Y}_{ik})^{2}$	nm-1
Regression due to $X_1, X_2, \ldots, X_{p+m-1}$	$\sum_{i=1}^{n} \sum_{k=1}^{m} (\hat{Y}_{ik} - \bar{Y}_{ik})^{2}$	p+m-1
Residual	$\sum_{i=1}^{n} \sum_{k=1}^{m} (Y_{ik} - \hat{Y}_{ik})^{2}$	m (n-1) - p
Test of p program coefficients:		
Total corrected for all means (b_o & $b_{p+1}, \ldots, b_{p+m-1}$)	$\sum_{i=1}^{n} \sum_{k=1}^{m} (Y_{ik} - \bar{Y}_{k})^{2}$	m (n-1)
Regression due to $X_1, X_2, \ldots, X_p$	$\sum_{i=1}^{n} \sum_{k=1}^{m} (\hat{Y}_{ik} - \bar{Y}_{k})^{2}$	p
Residual	$\sum_{i=1}^{n} \sum_{k=1}^{m} (Y_{ik} - \hat{Y}_{ik})^{2}$	m (n-1) - p

where

Y_{ik} denotes the predicted value of the dependent variable in the i^{th} year for the k^{th} source; $i = 1, 2, \ldots, n$; $k = 1, 2, \ldots, m$;

b_{jk} denotes the estimated coefficient of the j^{th} variable for the k^{th} source; $j = 1, 2, \ldots, p$;

X_{ijk} denotes value of the j^{th} variable in the i^{th} year for the k^{th} source; and

b_j denotes the estimated coefficients of the m-1 dummy variables, where $p < j \leq p+m-1$.

It is evident that model III simply combines separate equations of the form of model I.

The analysis-of-variance table (table 11) for model III differs from that for the second part of model II only in degrees of freedom.

A form of the partial F-test discussed in reference to model I may be used to test the significance of the difference between models II and III; that is, the hypothesis that the mp - p added parameters in model III are equal to zero. In this use, the partial F-ratio becomes:

$$F'' = \frac{\dfrac{\text{Regression SS Model III} - \text{Regression SS Model II}}{mp - p}}{\dfrac{\text{Residual SS Model III}}{m(n-p-1)}}$$

with the data available in rows three and four of table 11 and row six of table 10.

C: Selected Data Used in the Analysis

Tables 12, 13, and 14 present selected data series that are used in this analysis. Table 12 shows the program and price variables that are assumed for all States and regions. Table 13 presents for the various States and regions the size and type of farm data that are assumed for all years of the analysis. The feed-grain base for the three feed grains in 1969 is shown in table 14, along with proportions of the total made up by each feed grain. Other data items used for the study are easily found in published form.

Table 11.--Analysis-of-variance table for model III

Source of variation	Sum of squares	Degrees of freedom
Total (uncorrected)	$\sum_{i=1}^{n} \sum_{k=1}^{m} Y_{ik}^2$	mn
Total corrected for all means	$\sum_{i=1}^{n} \sum_{k=1}^{m} (Y_{ik} - \bar{Y}_k)^2$	m (n-1)
Regression due to $X_1, X_2, \ldots, X_{pm}$	$\sum_{i=1}^{n} \sum_{k=1}^{m} (\hat{Y}_{ik} - \bar{Y}_k)^2$	mp
Residual	$\sum_{i=1}^{n} \sum_{k=1}^{m} (Y_{ik} - \hat{Y}_{ik})^2$	m (n-p-1)

Table 12.--Data by years for which data are invariate by State, 1961-69

Item	1961	1962	1963	1964	1965	1966	1967	1968	1969
Time	1	2	3	4	5	6	7	8	9
Maximum diversion proportion	.40	.40	.40	.50	.50	.50	.20	.50	.50
Payment for 20- to 40-percent diversion: Dollars per bushel corn-equivalent	.72	.72	.63	.63	.63	.65	.68	.61	.61
Payment for 40- to 50-percent diversion: Dollars per bushel corn-equivalent	.60	.60	.63	1.38	1.38	.65	.68	.61	.61
Price difference, corn 1/	.19	.20	.18	.13	.08	.13	.06	.25	.22
Price difference, grain sorghum 1/	.24	.14	.16	.12	.03	.13	.11	.20	.20
Price difference, barley 1/	2/	0	.16	.14	.10	.07	2/	2/	.24

1/ These items correspond to the price-difference ratios for corn, grain sorghum, and barley in variable X_{i5k}.

2/ No barley program.

Source: January 15th market prices (12); program provisions and support rates (10, 13, and 14).

Table 13.--Data that are invariate by year, by State or region

State or region	Proportion of--	
	Feed-grains on cash-grain farms 1/	Feed-grain base on large farms 2/
Colorado	.39	.96
Kansas	.56	.94
Nebraska	.43	.98
North Dakota	.80	.97
South Dakota	.25	.98
Wyoming	.26	.89
Illinois	.64	.91
Indiana	.53	.81
Iowa	.32	.97
Michigan	.33	.63
Minnesota	.38	.93
Missouri	.42	.83
Ohio	.42	.69
Wisconsin	.09	.68
Arkansas	.23	.49
Louisiana	.12	.48
Mississippi	.10	.51
Oklahoma	.56	.85
Texas	.30	.92
Northwest	.73	.91
Southwest	.32	.98
Northeast	.26	.57
Southeast	.15	.62

1/ Source (3, table 22). Corn, grain sorghum, and barley harvested for grain on cash-grain farms as a portion of corn, grain sorghum, and barley harvested for grain on all commercial farms, 1964.

2/ Source (6, p. 36). 1964 base acreage on farms with bases of over 25 acres as a proportion of total 1964 base acreage.

Table 14.--1969 feed-grain base for corn, grain sorghum, and barley

State or region	Total feed-grain base	Corn base		Grain sorghum base		Barley base	
		Acres	Proportion of total	Acres	Proportion of total	Acres	Proportion of total
	1,000 acres	1,000 acres		1,000 acres		1,000 acres	
Colorado	2,444.1	532.4	0.218	1,220.3	0.499	691.3	0.283
Kansas	9,450.4	2,172.2	.230	6,174.8	.653	1,103.5	.117
Nebraska	9,937.2	7,553.9	.760	2,052.3	.207	331.0	.033
North Dakota	6,189.1	1,542.1	.249	2.2	1/	4,644.8	.750
South Dakota	5,864.4	4,895.1	.835	274.3	.047	694.9	.118
Wyoming	228.6	71.2	.311	3.2	.014	154.3	.675
Illinois	11,014.4	10,914.5	.991	28.2	.003	71.7	.006
Indiana	5,760.7	5,679.1	.986	21.8	.004	59.8	.010
Iowa	13,605.6	13,491.2	.992	92.4	.007	21.9	.002
Michigan	2,348.5	2,265.3	.965	.4	1/	82.8	.035
Minnesota	8,675.3	7,550.9	.870	5.4	.001	1,119.1	.129
Missouri	5,920.7	4,977.6	.841	703.5	.119	239.6	.040
Ohio	3,980.7	3,915.5	.984	1.7	1/	63.5	.016
Wisconsin	3,205.9	3,177.2	.991	.6	1/	28.0	.009
Arkansas	593.2	467.8	.789	104.3	.176	21.0	.035
Louisiana	501.8	483.9	.964	17.9	.036	.1	1/
Mississippi	1,401.1	1,336.9	.954	60.7	.043	3.5	.002
Oklahoma	3,130.6	286.9	.092	1,927.8	.616	916.0	.292
Texas	12,673.6	1,776.0	.140	10,355.0	.817	542.6	.043
Northwest	4,840.6	406.1	.084	12.2	.003	4,422.3	.914
Southwest	3,522.0	251.7	.071	1,233.6	.350	2,036.7	.578
Northeast	3,381.9	3,001.4	.887	30.9	.009	349.5	.103
Southeast	14,389.5	13,593.7	.945	384.7	.027	411.3	.029
Total	133,059.9	90,342.6		24,708.2		18,009.2	

1/ Less than 0.0005.

Source: (4).

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